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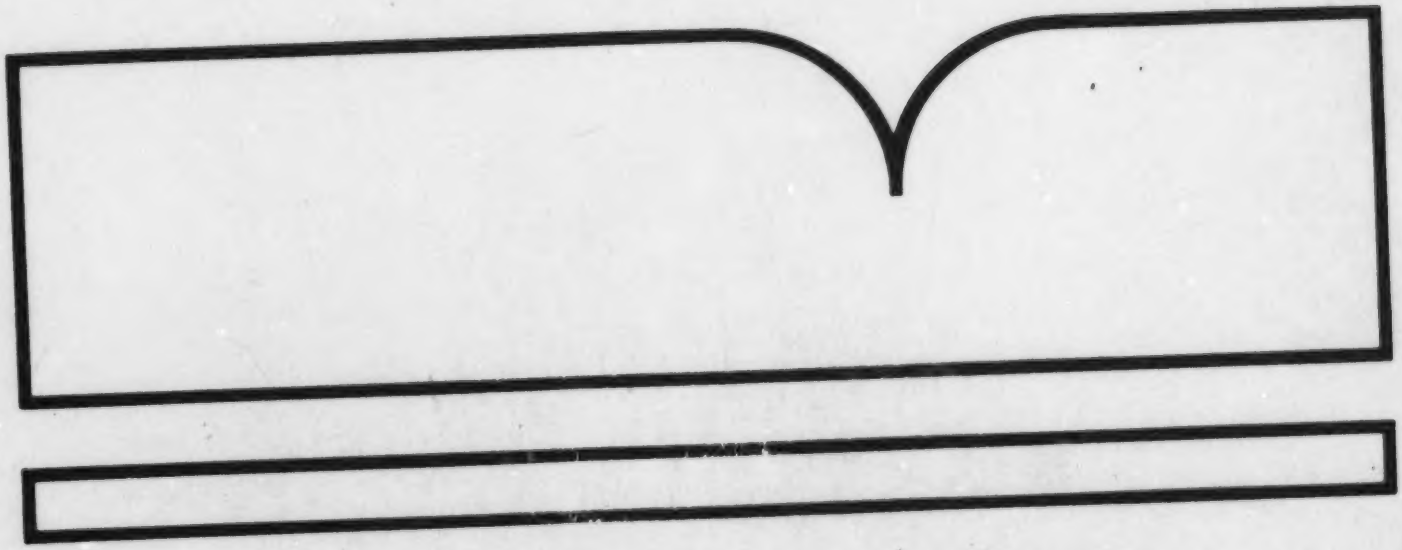

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16. ABSTRACT

Over 25 years ago workers recognized the adverse potential of fieldworker exposure to pesticide residues. Subsequent fieldworker acute organophosphate intoxications and resulting political pressure led to regulations by the Occupational Health and Safety Administration and the Environmental Protection Agency. These regulations and the worker reentry situation have been the subject of reviews. In this article, these reviews and conclusions will be discussed.

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Regional Considerations in Worker Reentry

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Over 25 years ago Carman and coworkers recognized the adverse potential of fieldworker exposure to pesticide residues (1). Subsequent fieldworker acute organophosphate intoxications and resulting political pressure led to regulations by the Occupational Health and Safety Administration and the Environmental Protection Agency. These regulations and the worker reentry situation have been the subject of reviews (2, 3).

The Milby report listed 18 reentry cases from 1949 to 1971 in California citrus (2). Gunther and coworkers cited 47 reentry incidents from 1949 to 1976 in California citrus (3). Peoples et al. reported 38 cases of occupational illness in California due to aldicarb exposure from 1974 to 1976 (4). Approximately 14 of these cases were due to exposure to aldicarb residues.

Peoples et al. (5) reported that 351 cases of occupational illness caused by parathion exposure were seen by California physicians in 1975. Seventeen of these cases can be regarded as worker reentry incidents. Knaak et al. (6) reported a case of 118 worker illnesses from dialifor exposure in a California grape vineyard in 1976. Davies et al. (7) reported 2 cases (24 fieldworkers) involving parathion in Florida sweet corn. In 1975, one death was reported from North Carolina workers reentering a parathion-treated tobacco field (8).

A major summary of reentry incidents from 1966 to 1979 classified 86 of 25,500 pesticide incident reports as reentry incidents (9). These reported cases included all classes of reentry incidents from pest control operators to fieldworkers. Of these 86, 47 were fieldworker reentry incidents (Table I). Nine states reported incidents. California had the highest number with 34 incidents, followed by North Carolina with 3. Sulfur led with 9 cases and parathion was involved in 6. All the sulfur cases were from California, usually involving eye irritation. Twenty-five different pesticides, covering all pesticide classes, were implicated in these reported incidents (Table II). But this summary must be judged incomplete as the

Table I. Summary of agricultural reentry incidents by state, 1966 to 1979 (from Ref. 8).

State	No. Incidents	No. Persons
California	34	62
Hawaii	1	1
Illinois	1	79
Indiana	2	77
Florida	1	17
Michigan	2	6
North Carolina	3	5
North Dakota	1	2
Washington	2	4
Total	47	253

Table II. Pesticides involved in agricultural reentry incidents (from Ref. 8).

Pesticide	No. Incidents
Aldicarb	2
Azinphosmethyl	2
Benomyl	1
Carbaryl	1
Carbofuran	1
Chlorothalonil	1
Copper sulfate	1
Demeton	1
Dichlorvos	1
Difolatan	2
Dimethoate	3
Disulfoton	1
Endosulfan	2
Lime	1
Malathion	2
Methidathion	1
Methomyl	2
NAA	1
Naled	2
Oryzalin	1
Oxydemetonmethyl	1
Parathion	6
Phosalone	1
Sulfur	9
Unknown	1
Total incidents	47
Total pesticides	25

1976 dialifor incident in California (118 persons) (6) and the cases reported by Peoples (4, 5) were not included.

The single most frustrating aspect of worker reentry episodes has been their unpredictability. This frustration was voiced by the Milby committee report (2) and in a major review of the California situation by Gunther et al. (3). Are the reported acute cases, in fact, the tip of an iceberg or do they fairly represent the actual frequency of such occurrences?

Reentry Classes

An examination of reported worker reentry incidents gives a clear picture of the immediate problem.

Sulfur. Symptoms of sulfur exposure were dermatitis and eye irritation. Incidents generally occurred within 1 to 4 days after application, but have occurred up to 3 weeks after application during mowing operations.

Carbamates (carbaryl, benomyl, carbofuran, aldicarb, methomyl). Symptoms of exposure were nausea, dizziness, blisters, dermatitis, malaise, sweating, tearing, breathing difficulty, and chest tightness. Usually, incidents have occurred within 1 to 2 days after application except for aldicarb (up to 4 days after application).

Chlorinated hydrocarbons (chlordane, endosulfan, and chlorothalonil). Symptoms of exposure were dermatitis, eye irritation, nausea, and dizziness. Entry into treated areas was from 0 to 1 day after application.

Organophosphates (parathion, naled, phosalone, dialifor, oxydemetonmethyl, dimethoate, azinphosmethyl, methidathion). Exposure to organophosphates resulted in headache, nausea, vomiting, dizziness, malaise, abdominal pain, and weakness. The organophosphates have been implicated in reentry incidents from 0 to 120 days after application.

Based on this record, worker reentry incidents can be placed in either of 2 classes. One class occurs shortly after application. Workers reenter a treated area by mistake or by design, and are exposed to toxic and fast-acting parent compounds. Additionally, these residues may be readily available to the worker because the field is still wet from the application itself or dew, or the residue is in a confined space such as a greenhouse or mushroom facility. Closer coordination between supervisor, the applicator, and fieldworkers; airing of greenhouses; and 1 or 2 day reentry times would easily preclude this class of reentry incident.

The second type of reentry incident involves entry into a treated area after a period of time usually considered safe: 5

to 120 days after application. This class of reentry incident has been limited primarily to California and to organophosphate insecticides, principally parathion and dialifor. This class has stimulated the research to date on worker reentry.

Reentry Research

The rarity of acute worker reentry illness has hampered research into this occupational illness. A North Carolina study of peach thinners exposed to foliar dislodgeable residues of 2.36 $\mu g/cm^2$ of parathion with 0.13 $\mu g/cm^2$ of paraoxon on fruit and 0.03 $\mu g/cm^2$ paraoxon on leaves showed no significant depression of either red blood cell (RBC) or serum cholinesterase (8). A California study of peach harvesters over 4 weeks, where both phosalone and azinphosmethyl had been applied, showed no depression of RBC cholinesterase (10). The dermal doses these subjects received ranged from 122 to 232 mg phosalone/week, 26 mg azinphosmethyl/first week only, and 2 to 3.4 mg phosalone oxon/week. Dislodgeable residues of azinphosmethyl on plant surfaces were 0.40 $\mu g/cm^2$ for the first week and not detected thereafter; phosalone ranged from 2 to 7 $\mu g/cm^2$ and phosalone oxon from 0.02 to 0.2 $\mu g/cm^2$. A similar experiment with apple thinners exposed to parathion (11) showed exposure ranging from 5 to 12 mg/hr depending on reentry time with dislodgeable residues of 1 to 5 $\mu g/cm^2$. No ill effects on the thinner were noted. A study of peach thinners in California showed no effect on RBC cholinesterase to thinners initially exposed to 2.6 $\mu g/cm^2$ azinphosmethyl on reentry. No residue was found in workers shirts, but urinary metabolites of azinphosmethyl were detected at levels up to 20 ppm by day 5 of exposure (12). Agricultural hand labor was studied in Washington using cholinesterase determinations and urinary metabolite analyses (13). No organophosphate residues were detected in urine and cholinesterase values were normal. In a study of peach thinners exposed to azinphosmethyl, the workers reentered the orchard only 12 to 18 hr after the application due to a 'misunderstanding' (14). Residues were about 2.6 $\mu g/cm^2$ of azinphosmethyl with very low azinphosmethyl oxon residues. Low urinary excretion of metabolites and a low (15% or less) cholinesterase depression were noted over 5 exposure days. In a reentry study of California citrus trimmers and pruners exposed to phosalone, results were unremarkable (15). No cholinesterase depression or urinary metabolites were noted. Reentry was at 14 and 21 days with exposure to 2.6 and 3.6 $\mu g/cm^2$, respectively, on each reentry day. In a major study of peach thinners (previously referenced, 12, 14, 16), lettuce harvesters, and artichoke harvesters, low or no urinary metabolites were observed and cholinesterase values were within the normal ranges. Phosdrin and methomyl had been applied to lettuce, and parathion and methyl parathion to artichokes. Dislodgeable residues were

less than 1 $\mu g/cm^2$. A human subject experiment to determine tobacco reentry after a monocrotophos application showed no urinary metabolites and insignificant cholinesterase depression when reentry was 48 hr or greater (17). These controlled studies are reassuring in that under 'normal' conditions illness of farmworkers from exposure to residue is apparently not common.

However, an examination of published worker reentry cases presents a frustrating problem. A compilation of incidents from 1949 to 1955 described cases of organophosphate intoxication from workers in pears, apples, grapes, citrus, and hops (18). Workers were picking, thinning, cultivating, and irrigating. Most cases occurred 8 days after application; 1 case occurred 33 days after application. Although these were descriptive cases, there is no doubt that they were real organophosphate intoxications. The first inkling of why residues made workers ill 8 or more days after application came in 1964 (19). Ninety-four orchard workers became ill when the parathion residue present should not have made them ill. Paraoxon was postulated to be the culprit. One residue sample contained more paraoxon than parathion. Sweet corn workers in North Carolina showed significant depression of RBC and serum cholinesterase after parathion exposure. The residues were 0.26 $\mu g/cm^2$ parathion, 0.35 $\mu g/cm^2$ paraoxon (24 hr residue) and 0.16 $\mu g/cm^2$ parathion, 0.23 $\mu g/cm^2$ paraoxon (48 hr residue) (20). No clinical symptoms were observed. The simple expedient of wearing gloves appeared to reduce cholinesterase depression (20). A recent episode involved 118 workers harvesting grapes treated with dialifor and phosalone (6). Based on previous information and the residue data, phosalone was not implicated. However, dialifor was more persistent in the San Joaquin central valley than anticipated and vineyards varied considerably in their dialifor content. Vineyards had been sprayed 15 to 40 days earlier. Cholinesterase values were reduced 49 to 58% in workers who became ill. Analyses of trousers, patches, and skin swabs indicated a higher level of residue on the worker than on the foliage. The skin swabs had approximately 10 times the level of foliage. Unfortunately, analyses for dialifor oxon residues were not performed until later (21). Analyses for dialifor oxon on a row by row basis showed possible spot treatment of rows and dialifor oxon residues were as much as one-third of the dialifor residues. It was speculated that dialifor oxon contributed to this reentry incident (21). Cotton scouts in North Carolina showed occasional RBC and serum cholinesterase depressions of 20 to 50% over 8 growing seasons after exposure to toxaphene-methyl parathion, EPN-methyl parathion, monocrotophos or azinphosmethyl 1 to 7 days after application (20). These depressions were linked to early reentry of fields (prior to 48 hr), entering dew-wet fields and poor personal hygiene practices such as wearing contaminated clothing more than 1 day (20).

A reentry study 12 hr after application in Arizona cotton, exposing volunteers to methyl parathion, ethyl parathion, or monocrotophos for 5 hr produced no clinical signs of poisoning. However, cholinesterase depression averaged 14%, and both ethyl-and methyl-parathion were found in the blood as well as p-nitrophenol (PNP) in the urine. These workers were not judged in jeopardy as cholinesterase depression was less than 30% and the PNP excretion was less than 4 mg following exposure (22).

The reasons for negative and positive results seem evident. Negative results appear linked with legal or extended field reentry and low oxon metabolites. Positive results appear linked with early field reentry and/or the presence of unexpected levels of organophosphate oxon metabolites.

Regionality

A common conclusion of 2 worker reentry reviews is that the worker reentry 'problem' differs in various regions (2, 3). If organophosphate pesticides regularly caused fieldworker intoxication, reports should be increasing. Farm labor advocates are increasingly vocal about pesticide exposure. They use this issue as a bargaining tool, and the agricultural community is cognizant of this concern. Carbamate and organophosphate pesticide use doubled from 1964 to 1976 (23). By weight carbamates represented 19% and organophosphates 50% of insecticides in use in 1976, up from 10% and 25% in 1964. Of all pesticides in use worldwide, 21% were in cotton and 32% in fruits and vegetables, crops which employ scouts or hand labor. These increases should result in more hazard and thus more cases of fieldworker intoxication. But there have been no such increases.

The lack of an increase in reentry incidents can be partly attributed to harvest times: that time a grower must wait after a pesticide application before the crop can be harvested (Table III). The control of food quality through residue monitoring was established in 1947 and reenforced in 1954 (24). Harvest times are generally longer than reentry times and do not vary regionally (Table III). Harvest times have probably prevented harvester illnesses, but this is not necessarily so. For instance, parathion in citrus has a 30-day national harvest time and a 2-day national reentry time, but up to a 60-day reentry time in California. Azinphosmethyl treated fruit may be harvested in 7 days, groves may be reentered in 1 day nationally, but not for 30 days in California. These differences reflect the experience of agricultural labor with pesticide exposure in various regions. By examining the factors which have contributed to a worker reentry incident, one can understand why the California experience has not been shared by the rest of the United States. We provide as an example a comparison of California with Florida.

Table III. Comparison of California and Florida citrus harvest and reentry times in days (from Ref. 31 and 41).

Pesticide	Harvest		Reentry	
	Calif.	Fla.	Calif.	Fla.
1. Azinphosmethyl	7 (28)[a]	7 (28)	30	1
2. Carbophenothion	30	14 or 30	14	2
3. Demeton	21	21	5	2
4. Diazinon	21	21	5	0
5. Dimethoate	15	15	4	0
6. Dioxathion	0	0	30	0
7. Ethion	0 (21)[b]	0 (21)	30	1
8. Malathion	7	7	1	0
9. Methidathion	14	14	30	0
10. Sulfur	0	0	1	0
11. Parathion	30	R.N.R.[c]	30, 45 or 60	R.N.R.

[a]28 days for two applications

[b]21 days for lemons

[c]R.N.R. = Registered but not recommended-2 day national reentry time; 14 or 30 day harvest depending on application rate.

[d]Depending on application rate

Reentry Factors

Four primary factors apparently lead to an incident 5 or more days after application: a dusty work environment, use of a sufficiently toxic organophosphate, conversion of the parent compound to its oxon metabolite, and dry conditions. The dusty working environment has been recognized since 1952 as a key element for transferring pesticides from leaf, fruit, and soil surfaces to a field laborer (1). The type of dust, i.e. soil type, also influences the rate of conversion of an organophosphate to its more toxic oxon form (3). And dry conditions are necessary for the persistence of these oxon residues over long periods of time (3).

Dusty conditions. Florida citrus is grown in primarily sandy soils with clay content of 2% or less (25). Clay is defined as particles of < 2 μ. Also, the Florida silt fraction contains less than 8% particulates 2 to 50 μ. California soils are reported as having over 10% particulates < 2 μ and 28 to 57% particulates from 2 to 50 μ (26, 27, 28). The limit for particulate matter swept up by grove operations and wind, i.e., airborne particulates which settle on foliage, is about 50 μ. Consequently, these data indicate a five-to-eightfold difference in the potential for dusty leaves and the transfer of soil surface residues to workers directly or via plant surfaces.

Pesticide use. California agriculture has a history of using ethyl parathion. This one compound has been implicated in almost every case of delayed reentry illness, with the recent exception of dialifor (2, 3, 6). Florida had difficulty with parathion applicator intoxication over 25 years ago which substantially reduced the use of ethyl parathion (29, 30). Also about 25 years ago, Florida citrus growers discovered that a decreased use of organophosphates assisted pest management by increasing the natural enemies of scale insects. Parathion is apparently not used in Florida citrus (30). Neither parathion nor dialifor is recommended for use in Florida citrus (31). Sulfur is recommended for one application per year in citrus and growers are clearly warned that sulfur is irritating to the eyes of applicators, loaders, and fruit harvesters (32); aldicarb may never be recommended for general use because of its toxicity (31). Similar events in California agriculture might have obviated their reentry problem.

Oxon metabolites. The organophosphate oxons have been a major factor in (0-120 days) worker reentry incidents (2, 3). This fact seems to have been lost in the search for a worker reentry 'solution'. Differences between California and Florida are again evident. In a study of ethion on grape foliage in the California central valley, ethion dioxon was above the level of

the parent compound in 7 days and the monoxon and dioxon combined were approximately 3 times the level of ethion after 28 days (33). A similar study in Florida citrus under various weather conditions found little ethion dioxon and less than 10% of the dislodgeable residue was the monoxon (34). Of 32 citrus groves in Tulare County, California, substantial paraoxon residues were found in 31 groves (35). In fact, on day 2 after application, one grove contained twice as much paraoxon as parathion, and paraoxon was about twice as long-lived as parathion in this study. Experiments in Florida citrus over a 2 year period under various weather conditions showed that dislodgeable paraoxon levels were always well below the level of parathion and disappeared at about the same rate (36, 37). Similar data have been reviewed (3). The point here is that oxon levels differ regionally in the United States and, in fact, regionally within California (3). This is reasonably well understood.

Environmental conditions--residue dissipation. It is well established that environmental conditions modify the behavior of pesticides (38). Long-term worker reentry (5 to 120 days) illnesses have been limited primarily to the hot and dusty central California valley. Since these incidents have been linked to the oxon metabolites and these metabolites reach higher levels in dry areas, rainfall and dew would appear to be additional major components for regionalizing the United States for worker reentry regulations. Davies et al. (7) proposed such a scheme in 1973.

Arizona citrus belts--	two wet seasons (July to September, December to February); mean annual precipitation 3" Yuma area, 7" Phoenix area, 11" Tucson area. Normal harvest seasons dry.
California citrus belts--	one wet season (November to March); mean annual precipitation 20" central district, 11" southern district. Except for navel oranges, normal harvest seasons dry.
Florida citrus belts--	no prolonged dry season; mean annual precipitation 52", higher south of Orlando, wet summers (8" in Orlando in July, 7" in Miami in June). Normal harvest seasons wet (7).

Beyond these differences in rainfall, most areas of the United States, excepting desert areas, have frequent dew condensation at night. In Florida, which is probably the extreme, dew presence ranges from 2 hr in the 'dry' winter to 12 hr in the 'wet' summer. In extensive and repeated studies of organophosphate insecticides and their oxon metabolites in Florida

citrus, the oxons have always been in low quantity (below the parent) and have dissipated rapidly (25, 34, 36, 37, 39). Rainfall has also been linked to oxon dissipation in California (3) and moisture to dissipation of oxons on soil surface particulates (40).

Reentry regions. Based on the factors contributing to a worker reentry illness, the United States could easily be regionalized using a combination of the following:

Areas of the United States with a history of incidents involving 5+ day reentry incidents should be regulated accordingly.

Those areas with very dry periods, particularly around harvest, may need special reentry regulations.

The soil type and its particulate profile determine the potential for transfer of pesticide to worker. This criterion is linked, however, to rainfall. Those areas with extended dry periods and a large quantity of particulate matter below 50 μ should receive closer attention.

Areas of the United States where the use of organophosphates (particularly parathion and dialifor) is low, have a low potential for acute fieldworker illness.

There are additional miscellaneous factors which impinge on the worker reentry process, the most important being: crop, pest management practices, work practices, and labor relations.

Most of the necessary information is currently available and could be woven into a flexible worker reentry regulatory model. Such a model would regionalize worker reentry regulations.

Regulatory Options and Research

There appear to be 3 viable regulatory options:

(a) Continue the present system of 1 or 2 day reentry intervals for selected chemicals, the decision for longer intervals being left to the states.

(b) Flexible reentry intervals based on toxicity, residue behavior, and exposure mechanisms.

(c) Monitoring of pesticide levels prior to reentry.

Each option has problems. The present system, option (a), is limited to 14 organophosphates. This leaves unregulated many chemicals which have caused worker illnesses, so it would seem reasonable to extend a 1 or 2 day reentry time to all agricultural chemicals. This approach would provide a base for longer reentry times where necessary, such as in California. Another weakness of the present system, however, is the 24 and 48 hr times. The intent of these regulations might be better served by requiring full working days to elapse after the day of application prior to reentry. This would extend reentry times slightly, but would remove the guesswork as to when the

application was actually completed. This regulatory approach requires little, if any, additional research.

Flexible reentry intervals, option (b), would regionalize worker reentry regulations. Of necessity, this approach would involve a reentry model as a base. A model would set priorities, i.e., the relative importance of factors which lead to an acute reentry pesticide intoxication. Much of the necessary information is available for such a model: weather data, some information on oxon levels, some pesticide use data, actual worker reentry studies, and acute dermal toxicities. For the ultimate success of this approach, there are some important factors which need investigation. The tendency of pesticides to convert to a more toxic product and the parameters (environmental and otherwise) affecting the conversion rate, need further investigation. The dermal toxicity of pesticides and their more toxic environmental products would be required. The dermal dose a worker receives as related to work practices, soil type and foliage levels is a key factor. But the model could be constructed now with the available information and updated as data becomes available. The process is really not very complicated and reasonable priorities could be set on worker reentry 'factors'. This approach appears to be the most practical long-term solution because it would allow screening of compounds prior to use and would lead to an indepth understanding of fieldworker exposure, from work practices to human toxicology.

Monitoring of fields for residue levels is currently in use in California. This approach reflects the unpredictability of worker reentry incidents in California. Present scientific and empirical evidence, however, suggests that monitoring is not needed in other regions.

Reentry regulations should be promulgated only after carefully considering the accuracy of the applicable data. Many reported incidents are will-o-the wisp cases. The physician has only the patients' word and a few symptoms for a diagnosis. Conversely, the worker and his foreman would probably never correlate increased 'sick days' with periods of pesticide application. Sometimes union activities and human suggestibility are involved. Sometimes the social aspects of big agriculture and exploited labor are involved. Agriculture has a diametrical anathema to <u>any</u> regulatory decision for which they see no immediate and personal justification. Reason dictates that all aspects of the reentry issue be considered.

The option suggested, the reentry model, can be constructed now. But the future requires enlightened, humane practices governing agricultural labor exposed to pesticides that continued careful investigation should help foster.

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